SOPC WORLD 2002

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Designing Embedded Processors in FPGAs

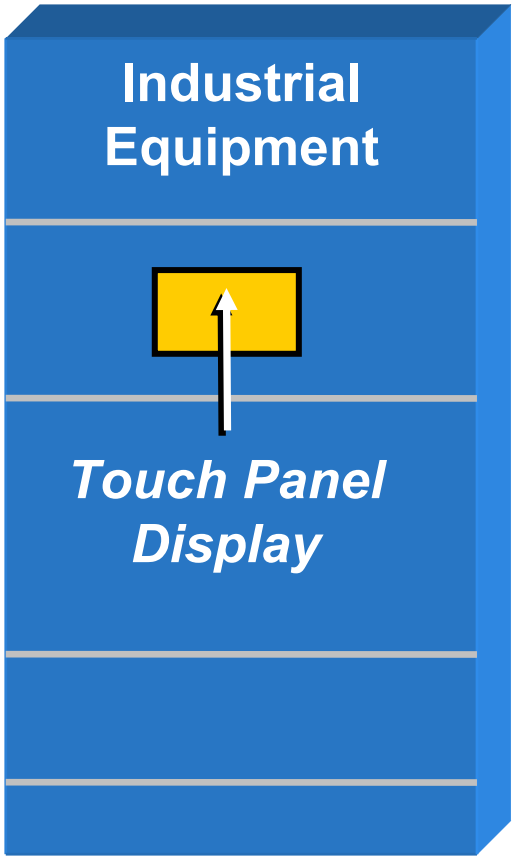
ALTERA.

Agenda

- Industrial Control Systems
- Concept
- Implementation
- Summary & Conclusions

Industrial Control Systems

- Typically Low Volume
  - Many Variations Required
- High Customization
  - Number of Attached Sensors
  - Types of Attached Sensors
  - Required User Interface Needs
  - Storage & Recording Needs
- Touch Panel Displays
  - Increasing Use to Reduce Cost



Concept

Flexibility

Need to Easily Modify Design Allowing for Customization or Feature Enhancements

Reaction to Customer Needs

Changing Solution Needs: New Sensors/ New Control

Time to Market

Capability to Complete Development Work for Solution in Time to Meet Specific Market Window

Reusability

Ability to Reuse Much of Existing Design As Starting Point for New Solution

Rapid Design of New Control Solutions

Concept

- Solution Requirements
  - Minimal Cost
    - Overall Solution Measured Not Only By Cost of Components, But Cost of Board
    - The Lower the Solution Cost, The Easier It becomes to Win Business & Sustain Margins
  - Manufacturability
    - Can Existing Implementation Be Maintained If Devices Fail – i.e., Is Supply Guaranteed?
  - Device Qualification
    - If Company Has Stringent Device Qualification Needs, Advantages of Utilizing Single Device for Many Applications Becomes Apparent

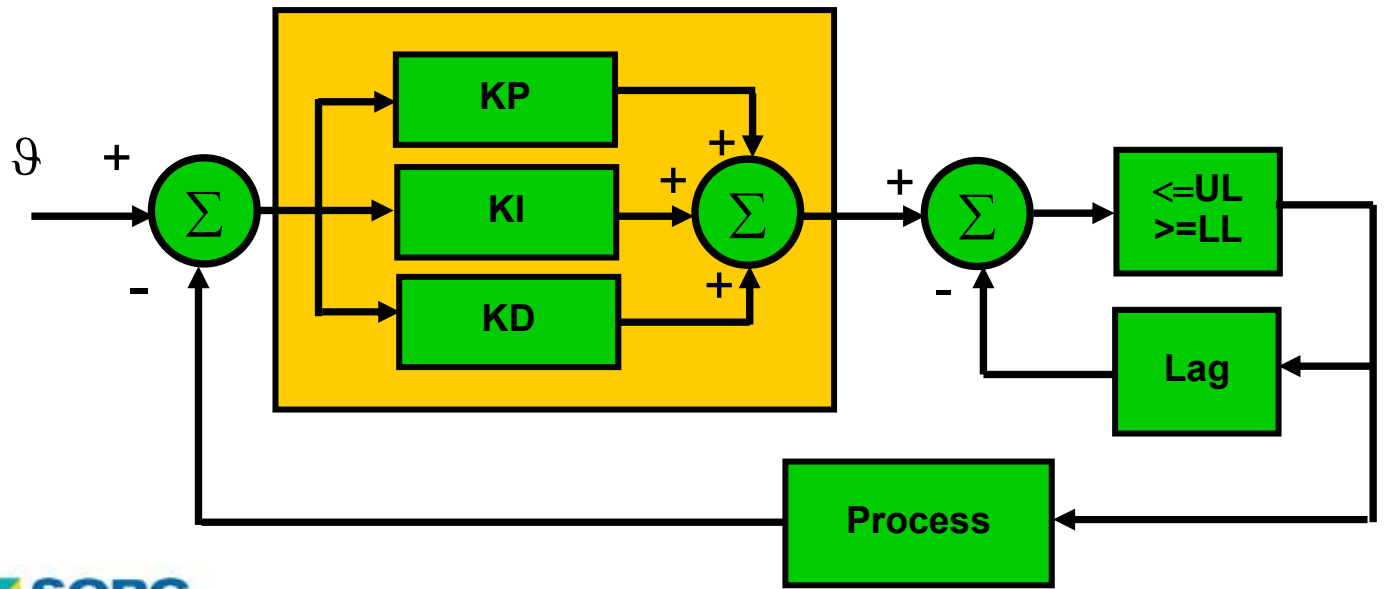
Conceptual Solution

- Industrial Control Flow Diagram
- Hardware Block Diagram
- Software System

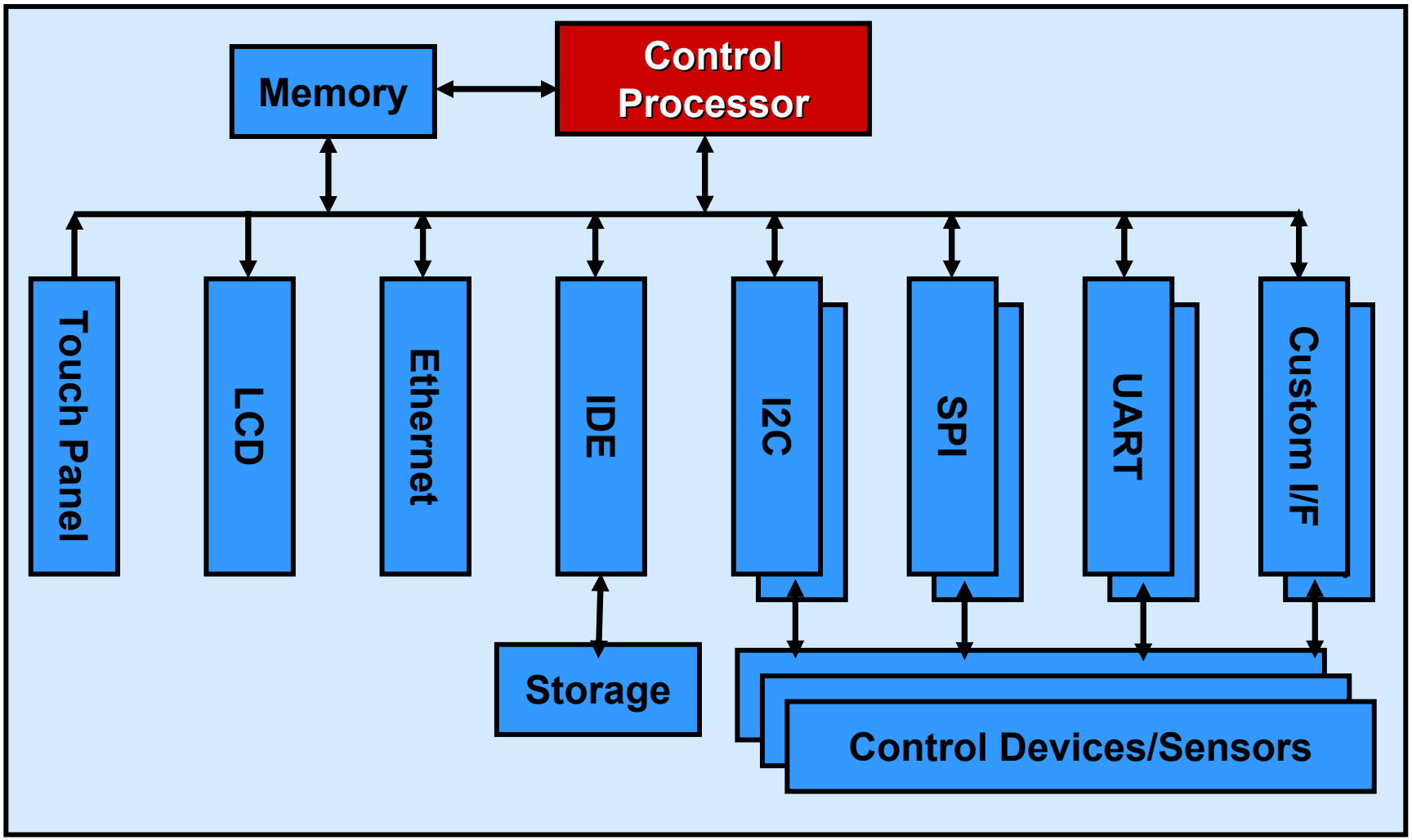
Industrial Control Flow Diagram

- Example: PID Controller
- Typical Transfer Function

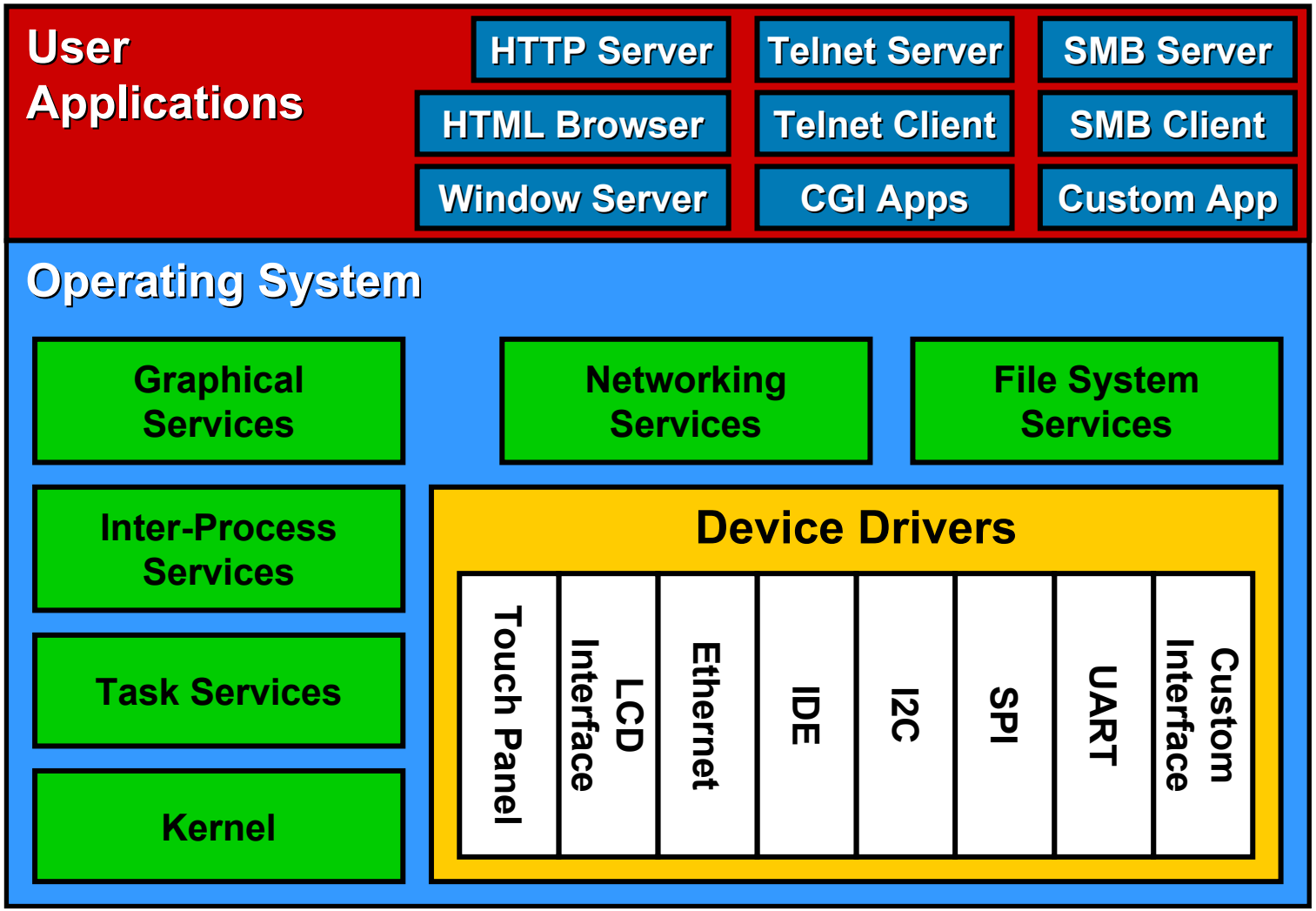
$$\frac{Y(s)}{U(s)} = \frac{K_D s^2 + K_P s + K_I}{(m + K_D)s^2 + (b + K_P)s + K_I}$$



Hardware Block Diagram



Software System



Implementation

- Selected System Components
  - Cyclone FPGA
  - Nios Embedded Processor
  - μCLinux Software
- Solution Development

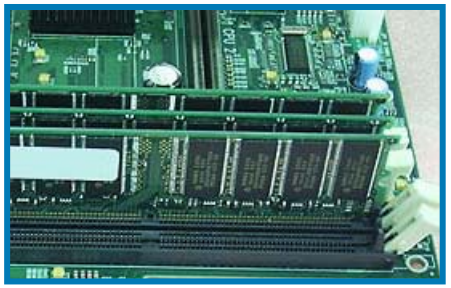
Cyclone FPGA

- Advantages
  - High-Density, Full-Featured FPGA
    - Maximizes Flexibility, Avoids Obsolescence & Device Qualification Issues
  - Low Cost
    - Reduces Production Costs without Reducing Solution Functionality
  - High Performance
    - Maximizes Longevity of Solution & Functional Economy
  - Migration Path
    - Enables Same Board to Be Used for Different Solutions
  - Enables High Levels of Integration
    - Minimizes Component Count & Board Costs

Powerful Cyclone Functionality

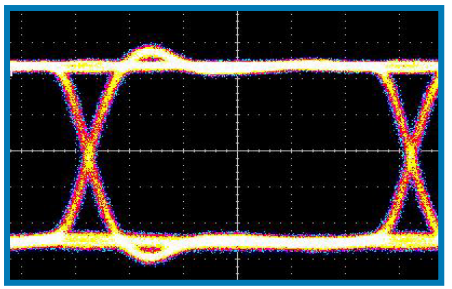
External Memory Interface

- Dedicated SDRAM & FCRAM Interface Circuitry
- 266-Mbps Performance



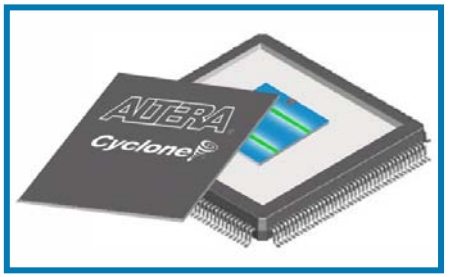
Differential Signaling

- 311-Mbps Performance
- Up to 129 Channels



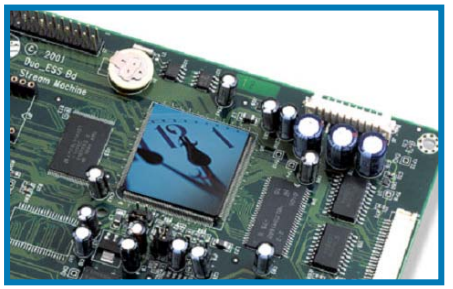
Embedded Memory

- Up to 294,912 RAM Bits
- 200-MHz Performance



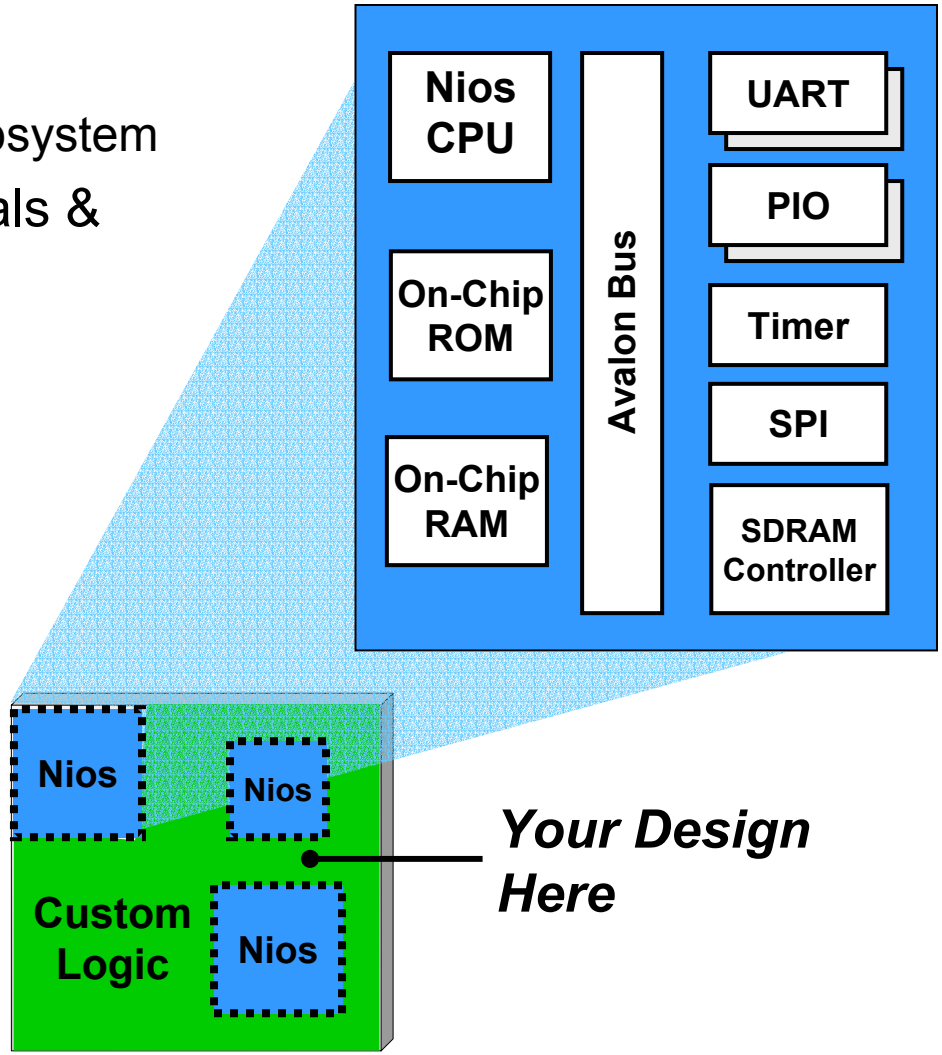
Phase-Locked Loops

- System Clock Management Features
- Up to 2 PLLs



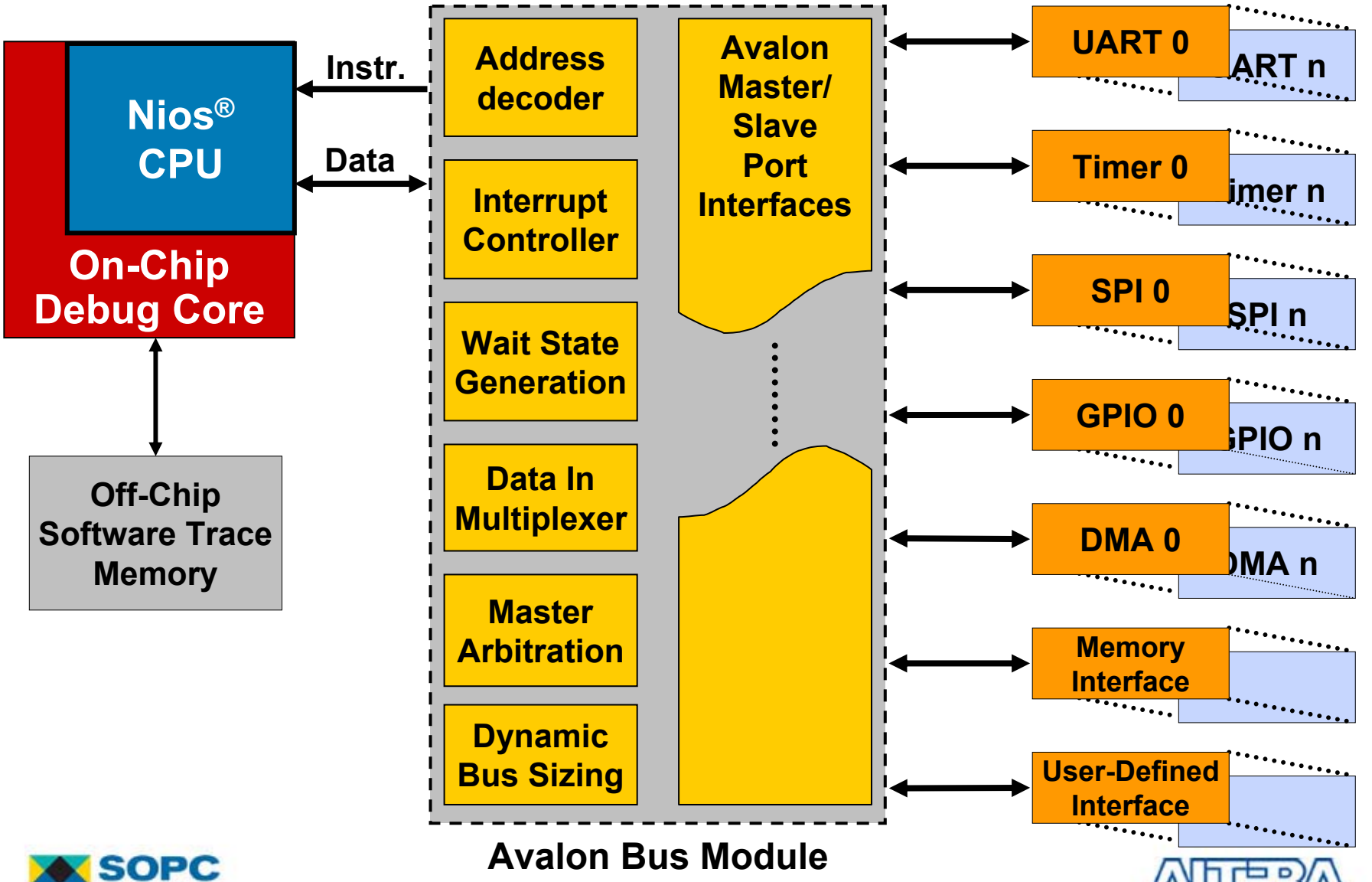
Nios Processor Systems

- Not Just A Processor
  - Complete Microprocessor Subsystem
- Processor Core Plus Peripherals & Memory Interfaces
- Custom Peripherals
- Custom Instructions
- Simultaneous Multi-Master Avalon™ Bus Connects All Components
- Multiprocessor Systems Possible



PIO: Parallel I/O
SPI: Serial Peripheral Interface

Nios System Architecture

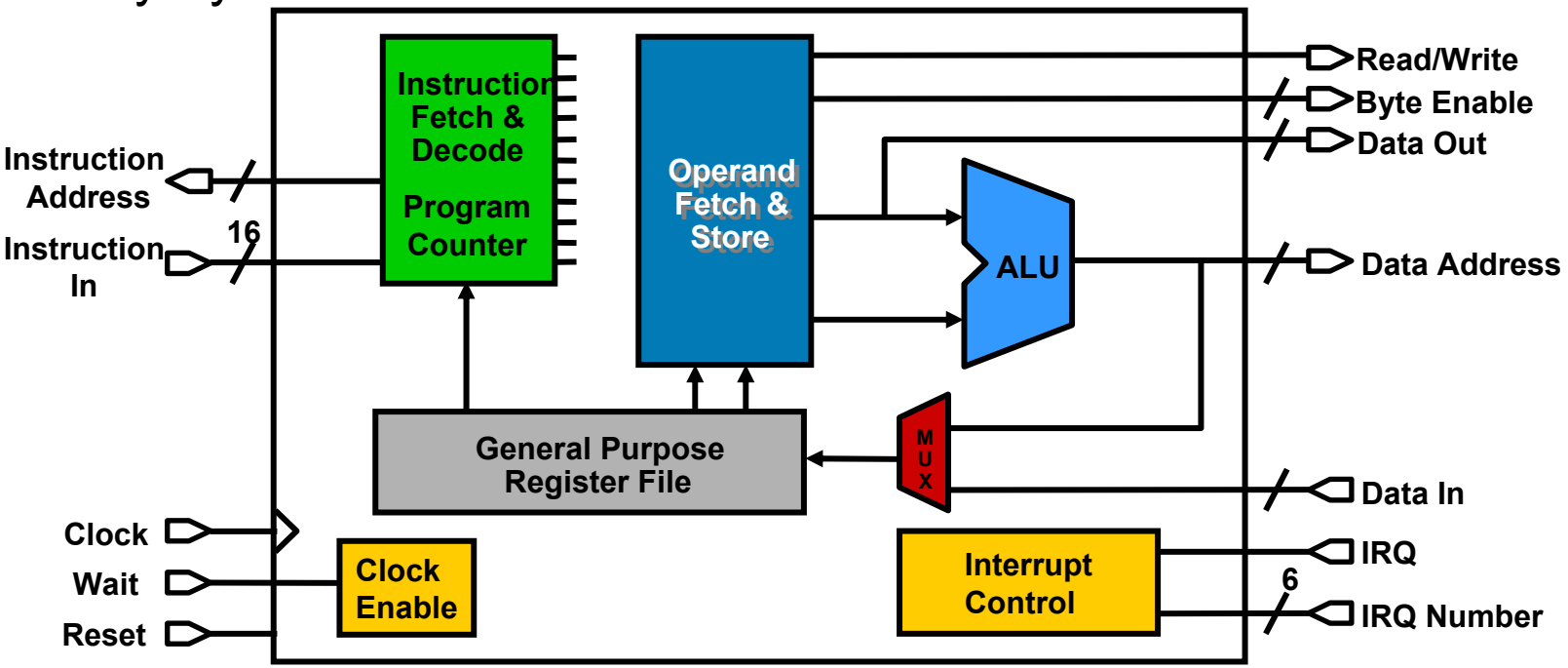


Peripheral Components

- Memory Interface
  - On-Chip
    - RAM, ROM
  - Off-Chip
    - SDRAM Controller
    - SSRAM
    - SRAM
    - Flash, ROM
- DMA Controller
  - Memory-Peripheral
  - Memory-Memory
  - Peripheral-Peripheral
- Bridges
  - AHB to Avalon™ Bus Bridge
- Parallel I/O (PIO) Registers
  - General-Purpose I/O Registers (PIO)
    - Input
    - Output
    - Bidirectional
  - User-Defined Interface
- Serial I/O
  - UART
  - SPI
- Timer
  - Simple Timer
  - Pulse Generator
  - Watchdog Timer

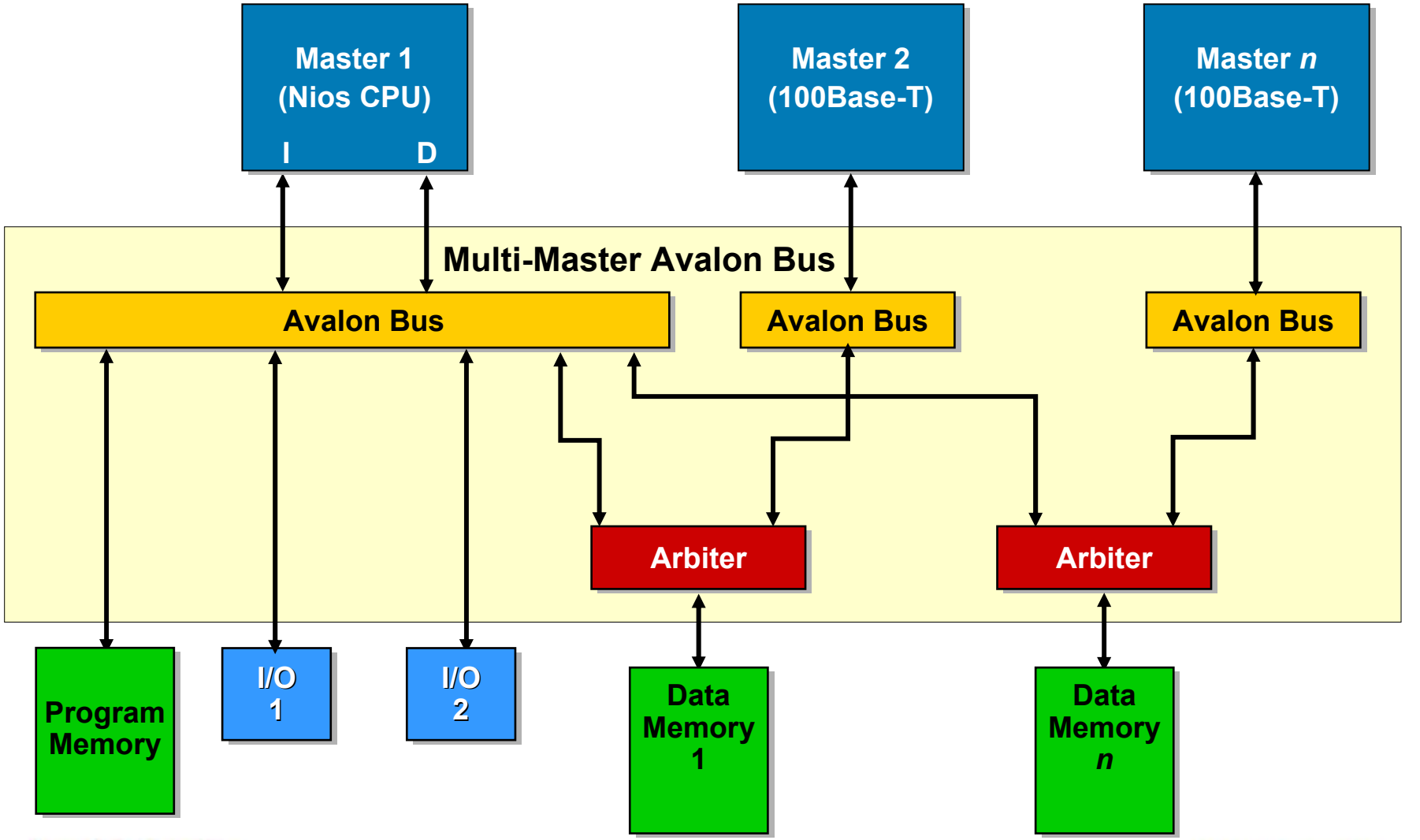
Nios Embedded Processor

- Standard RISC Components
- Optimized for Size & Performance in PLDs
- Fully Synchronous Interface

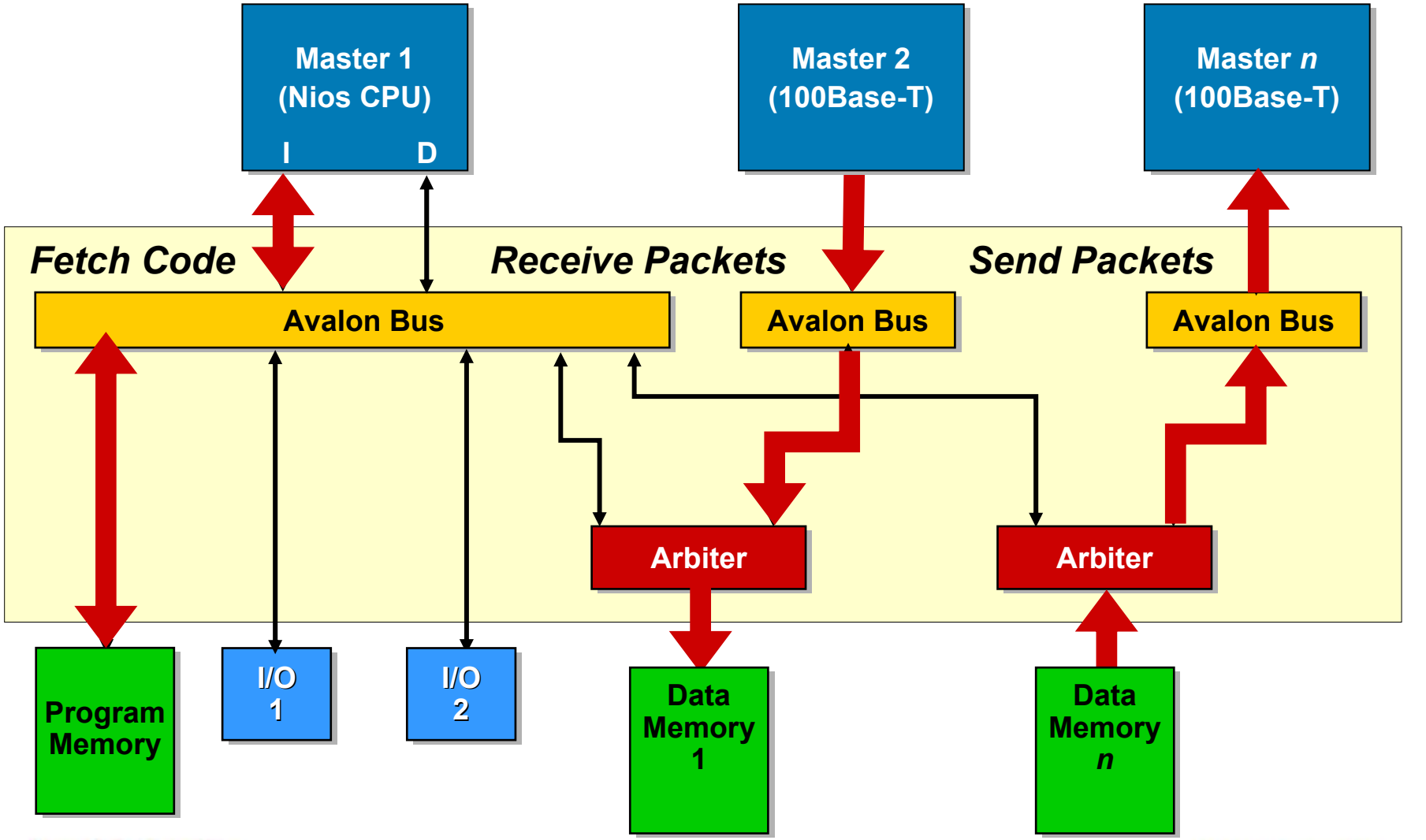


IRQ: Interrupt Request
ALU: Arithmetic Logic Unit

Simultaneous Multi-Master Bus

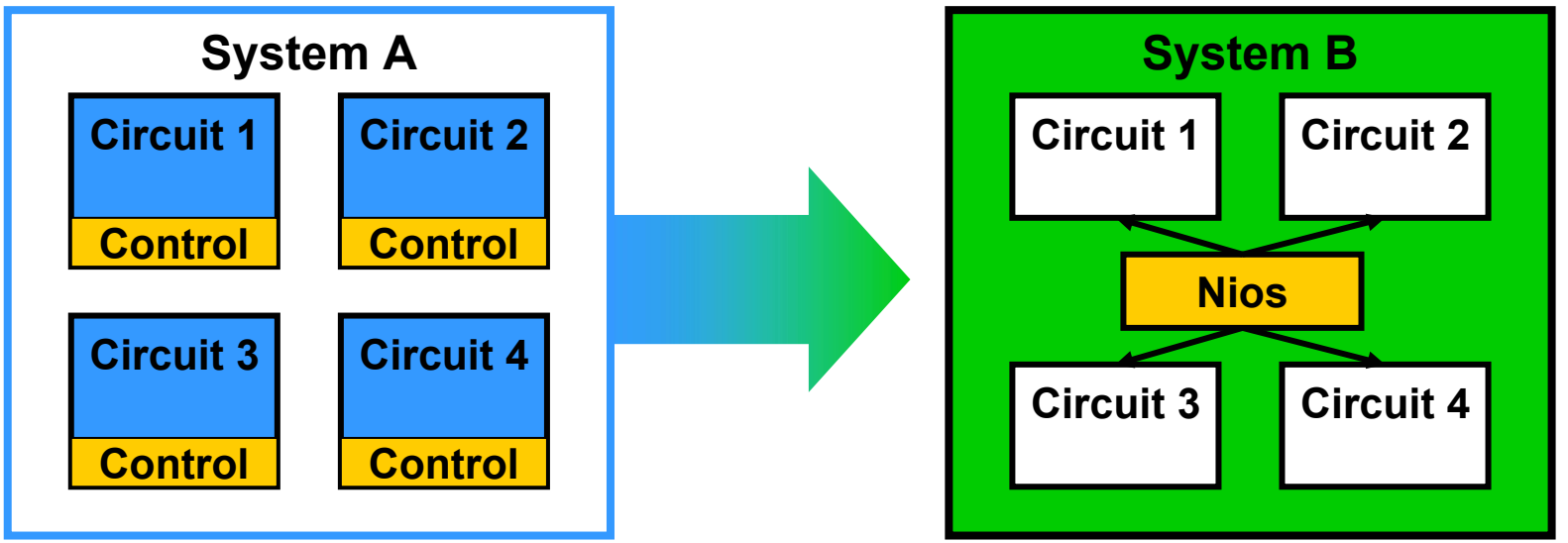


Simultaneous Multi-Master Bus



State Machine/PLC Replacement

System	A	B
Development Complexity	High	Lower
Development Time	High	Lower
Resource Utilization	High	Lower
Design Flexibility	Low	Higher



Nios Embedded Processor

- Advantages
  - Highly Configurable
    - 16-,32-Bit Variants, Add Peripherals as Required
  - Optimized For PLD Implementation
    - Minimal Size, Reduces Device Costs
  - Royalty Free
    - No per Product Fee
  - Low Cost
    - Minimal Investment
  - Obsolescence Proof
    - Migration to New Altera® Device Families
    - Longevity Associated with Altera Device Families

µCLinux Software

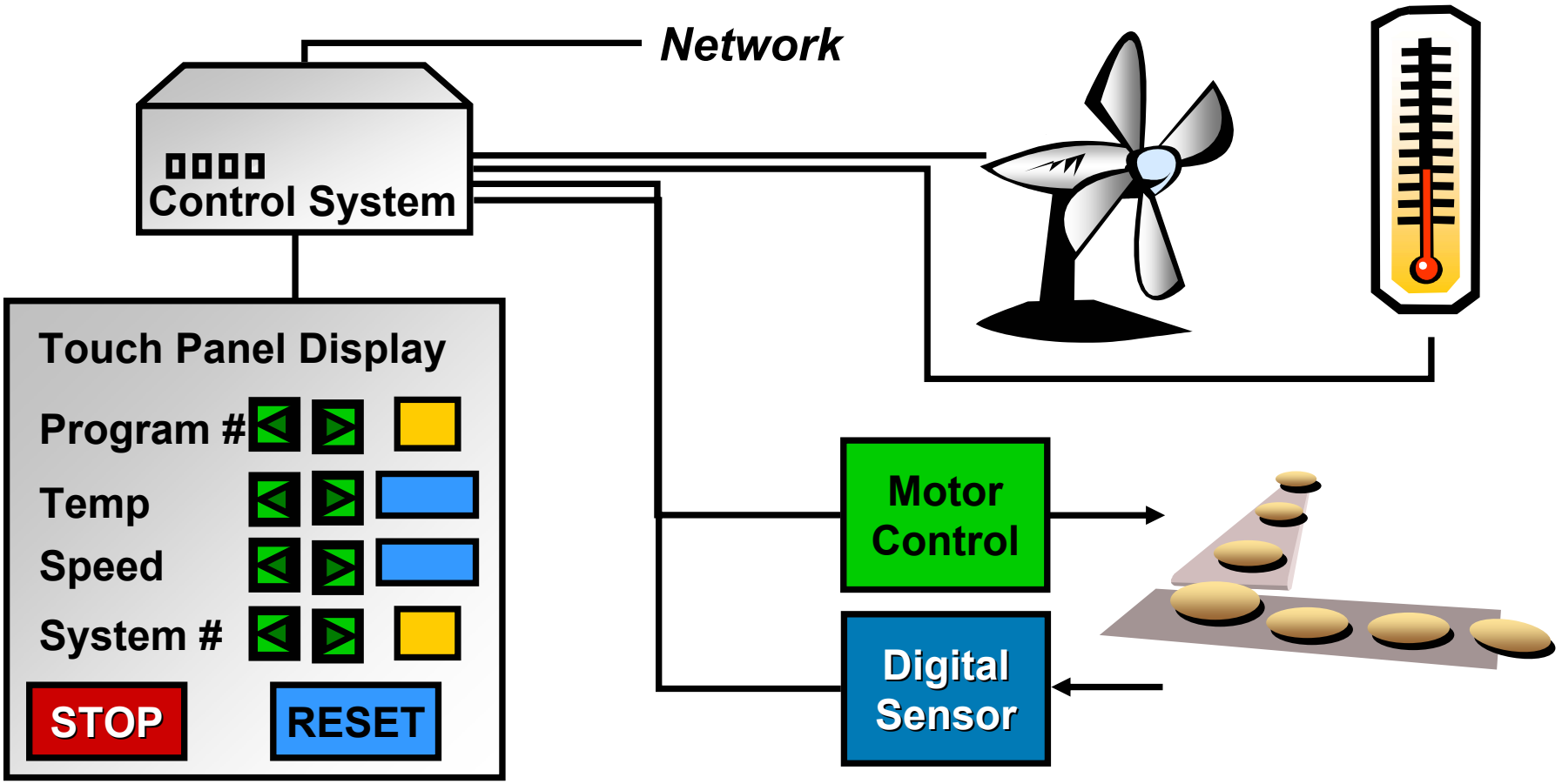
- Linux 2.4
- C++ Support
- µClibc Embedded Library
- Source Code Provided
- SOPC Builder Support
- Fully Supported in Cygwin Environment

µCLinux Software

- Advantages
  - Open Source Environment
  - Availability of Solutions Simplifies Development
    - HTTP Server, HTTP Browser, Telnet Server, Telnet Client
  - Driver Availability
    - Large Driver Resource
    - Ability to Integrate Custom Drivers
  - Integration with Altera Tools
    - Quartus® Software
    - SOPC Builder

Solution Development

- Example System: Cookie Factory



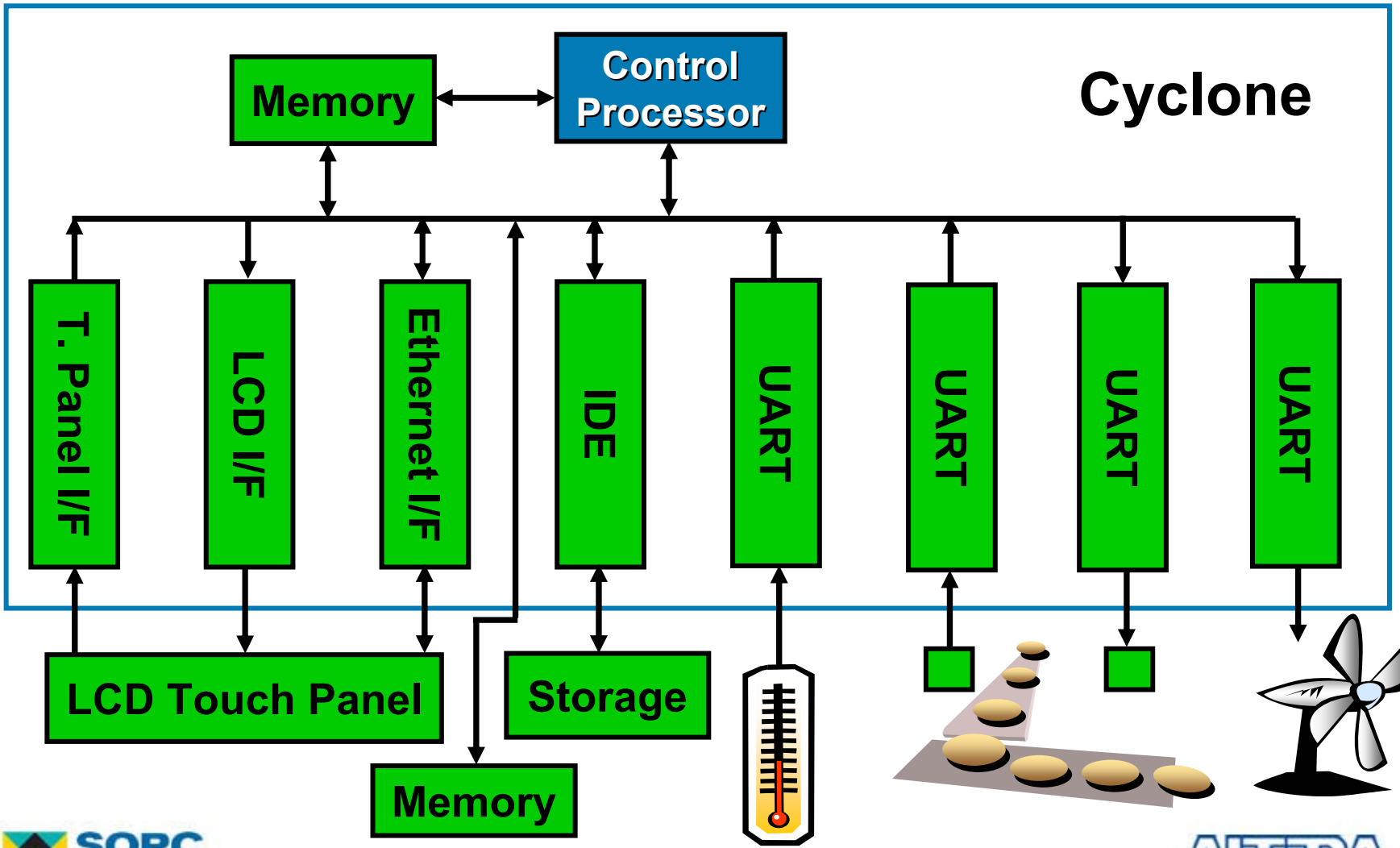
Solution Development

- Cyclone Logic Element Implementation Cost

Block	LEs
16-Bit Nios	900-1,100
LCD I/F	100-2,500
Touch Panel I/F	200-5,000
Ethernet	100-2,500

Block	LEs
IDE Interface	100-200
Customer Interface	200
UART, SPI, I2C	200-300
CAN	100

Solution Development



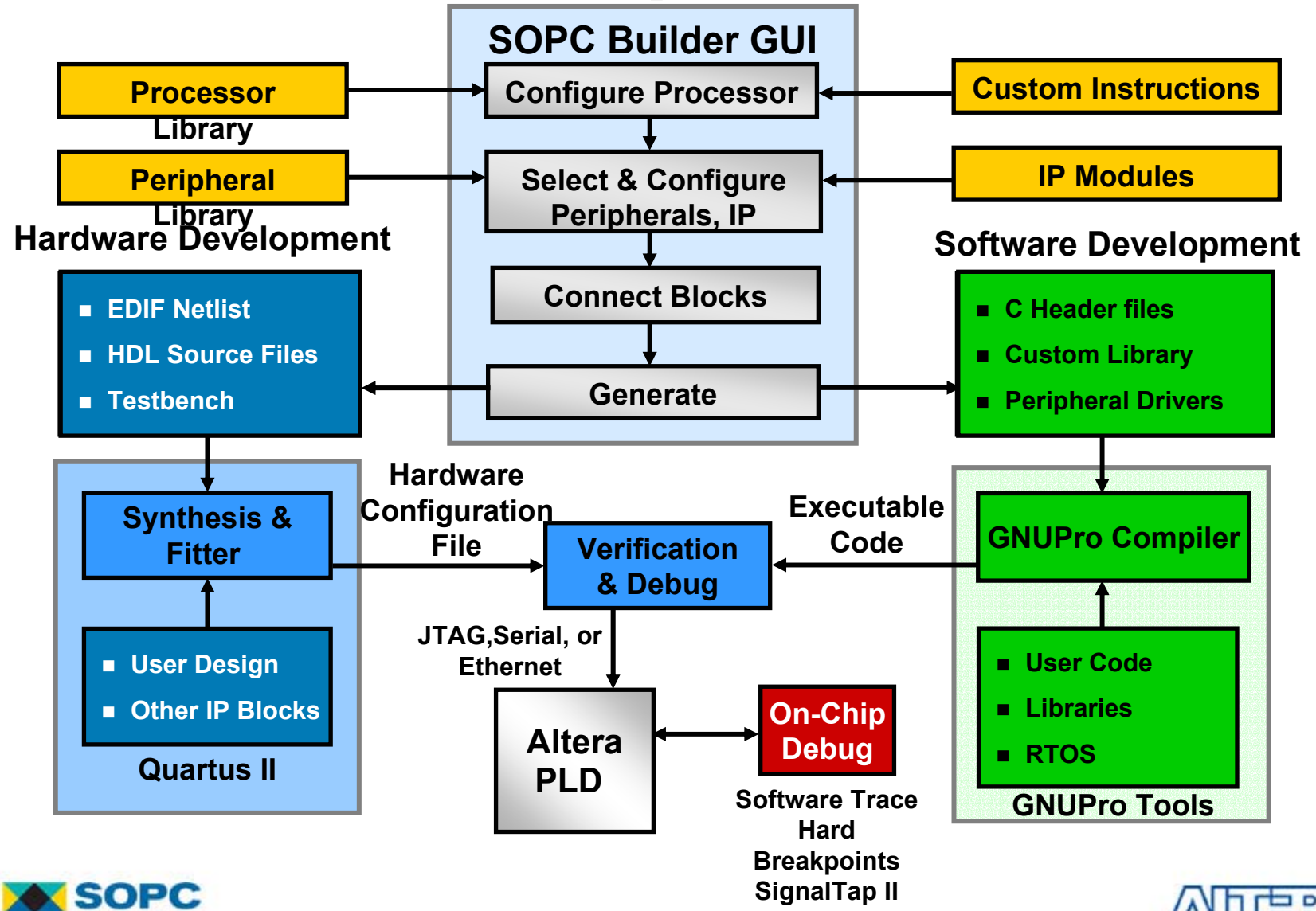
Solution Development

Function	Amount	LE Cost	Total
Processor	1	1,200	1,200
UART	4	300	1,200
Touch Panel Interface	1	500	500
LCD Interface	1	700	700
Ethernet Interface	1	100	100
IDE	1	100	100
		Total	**3,800**

Solution Development

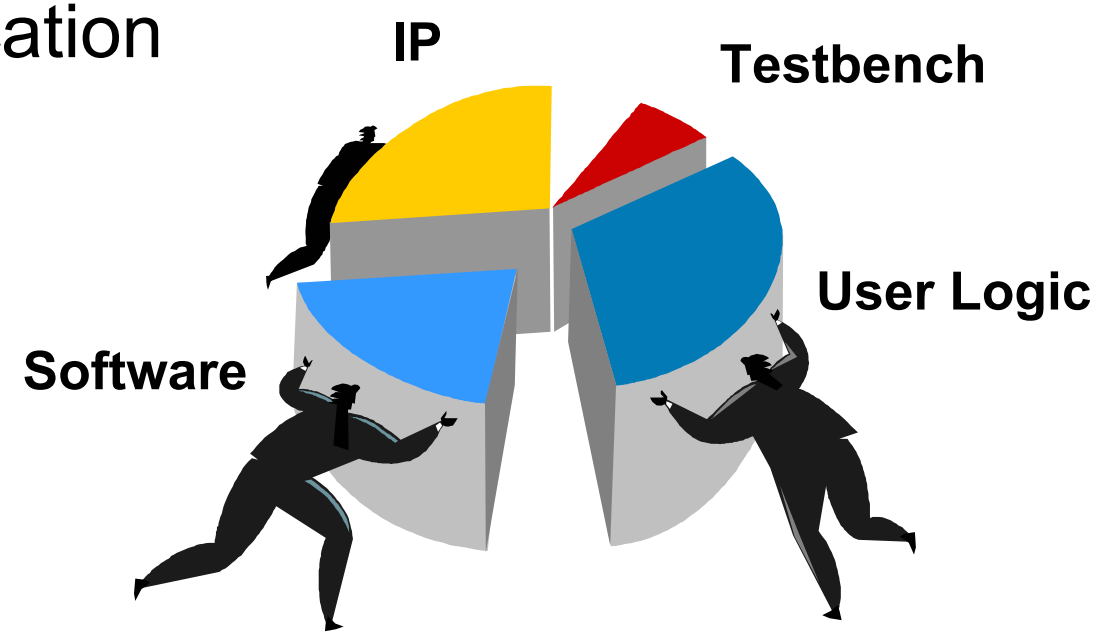
- EP1C6 Has 5,980 Logic Elements
- Solution Requires 3,800 Logic Elements
- Device 63.5% Utilized
- Memory Requirements
  - EP1C6 Has 92,160 RAM Bits
  - External Memory Only for LCD Image Memory
    - 614,400 RAM Bits Required for QVGA

Solution Development

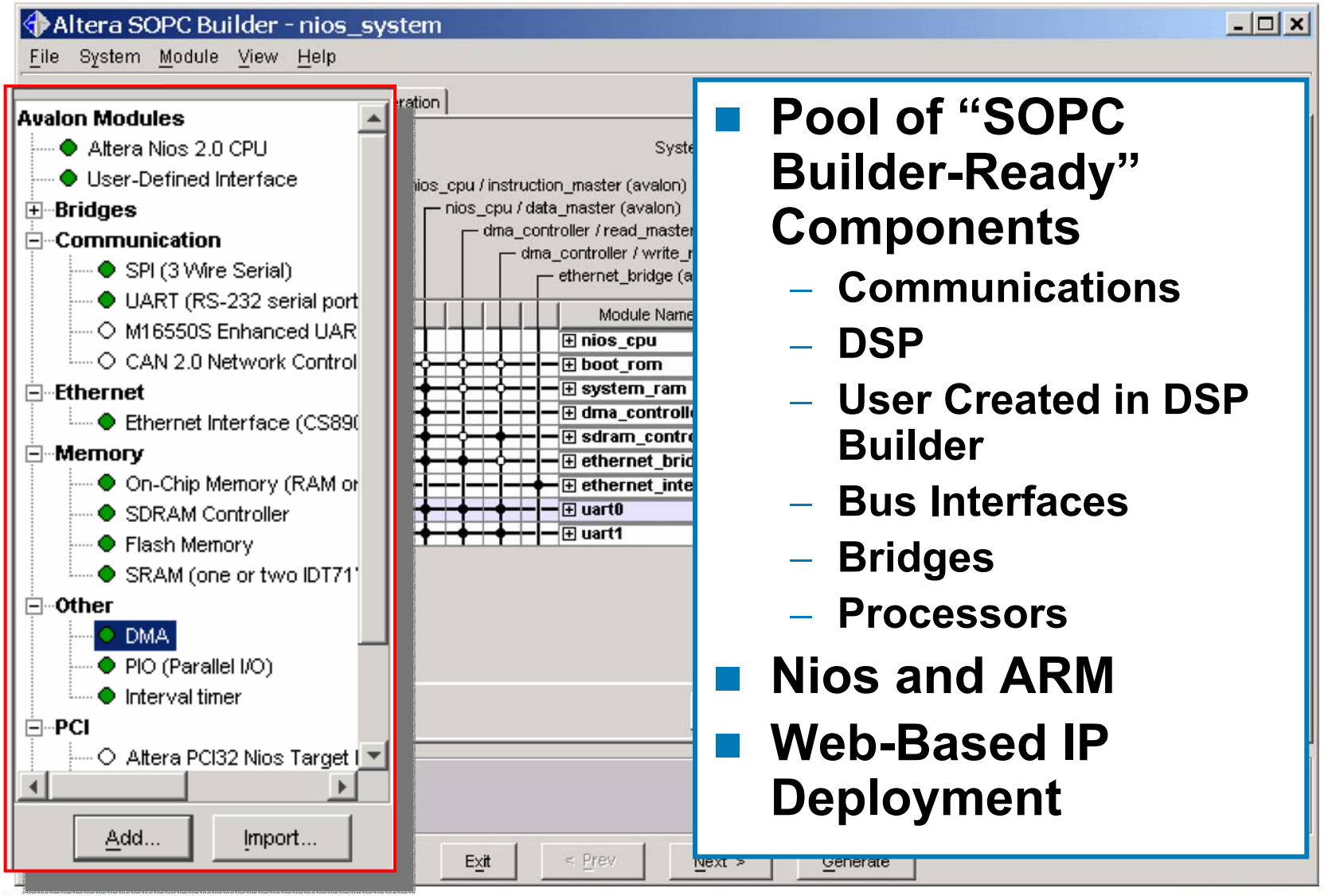


SOPC Builder Design Tool

- System Customization
- Component Integration
- Software Generation
- System Verification



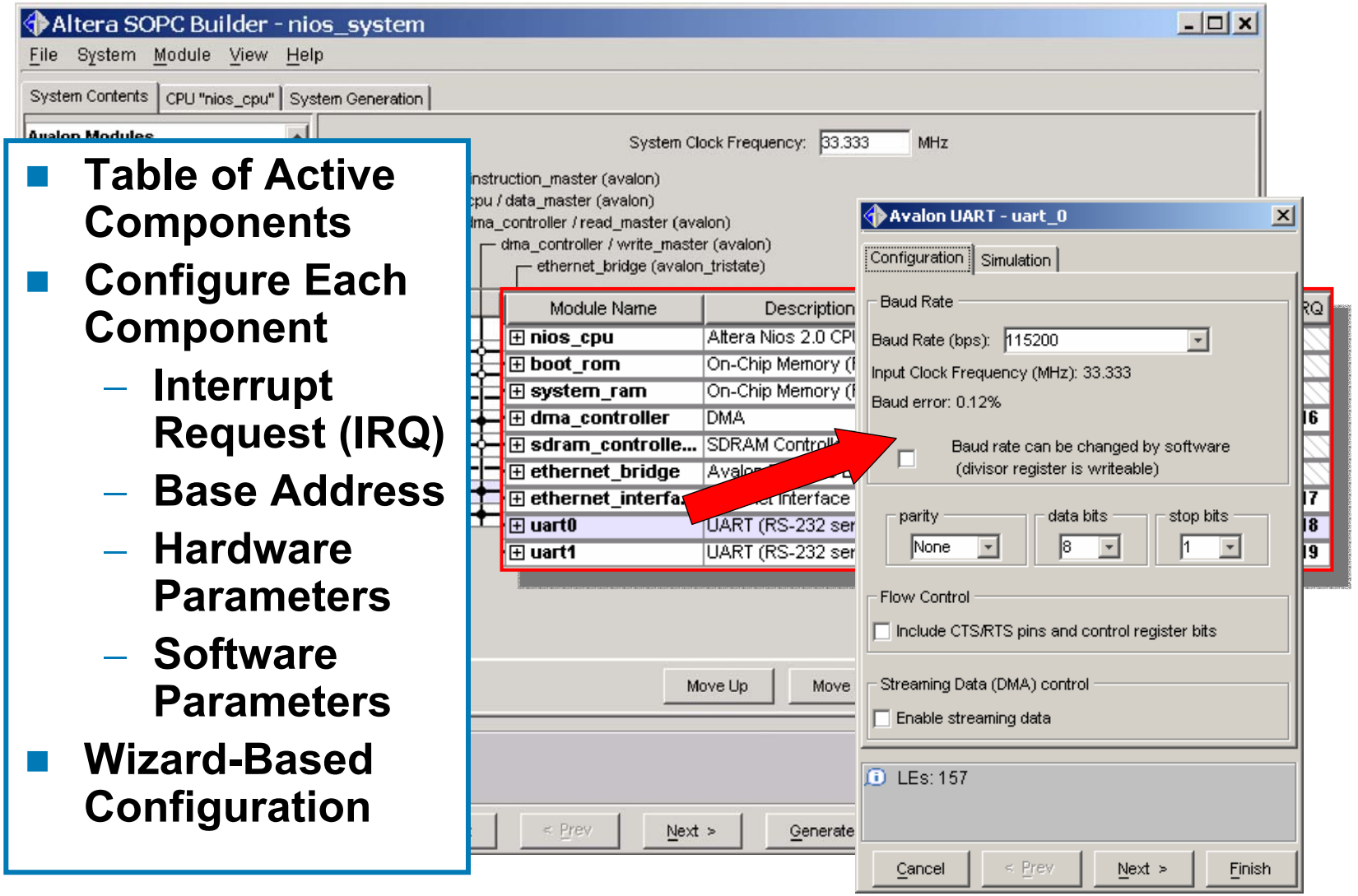
SoPC Builder - Customization



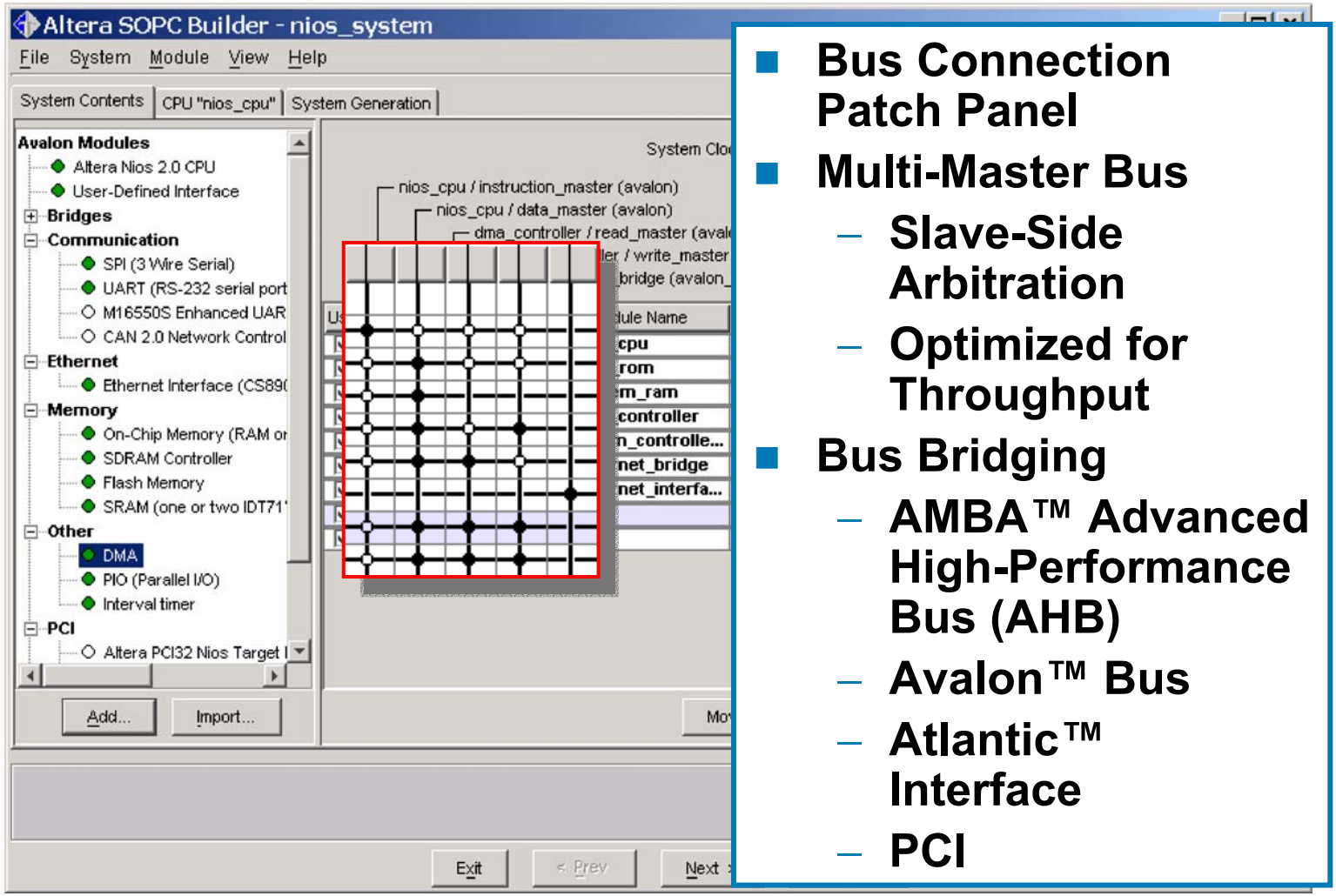
- Pool of "SOPC Builder-Ready" Components
  - Communications
  - DSP
  - User Created in DSP Builder
  - Bus Interfaces
  - Bridges
  - Processors
- Nios and ARM
- Web-Based IP Deployment

SoPC Builder - Customization

- Table of Active Components
- Configure Each Component
  - Interrupt Request (IRQ)
  - Base Address
  - Hardware Parameters
  - Software Parameters
- Wizard-Based Configuration



SoPC Builder - Integration



- Bus Connection Patch Panel
- Multi-Master Bus
  - Slave-Side Arbitration
  - Optimized for Throughput
- Bus Bridging
  - AMBA™ Advanced High-Performance Bus (AHB)
  - Avalon™ Bus
  - Atlantic™ Interface
  - PCI

Nios OS / RTOS Support

Provider	Product	Description
Accelerated Technology	Nucleus PLUS	Royalty-Free, Source-Available RTOS
Mapusoft Technologies	OSChanger	Tool to Convert pSOS / VxWorks Applications to Nucleus PLUS
Microtronix	µClinux	Open-Source OS
Shugyo Design	KROS	Small-Footprint, Royalty-Free, POSIX-Compliant RTOS
MiSPO Co., Ltd.	NORTi	µITRON 4.0-Compatible Real-Time Kernel

Nios Debug Solutions

Provider	Product	Description
Viosoft	Arriba!	IDE with Integrated Support for Nios On-Chip Debug Module - Hardware Breakpoints & Processor Trace
Microtronix	Debugger Module	External Memory Daughter Card for Use as Software Trace Capture Buffer
Microtronix	OCD Solutions Kit	Insight (gdb) Debugger Enhanced to Support Hard Breakpoints & Software Trace
Sophia Systems	WatchPoint	Full-Featured Debug Environment with Advanced On-Chip Debug Support
Red Hat	GDB / Insight*	Software Debugger
Altera	Tracelink*	Interface to Nios On-Chip Debug Module Hardware Breakpoints & Processor Trace

* Included in Nios Development Kit

Nios Development Kits

- Altera
  - 10/100 Ethernet Development Kit
  - PCI Development Kit
    - 32-Bit 33-MHz PCI Master/Target
    - PCI Bus Hosting Features
- Third Party
  - Linux Development Kit
    - IDE Interface
    - Compact Flash
    - SDRAM Controller
  - VGA/LCD Touchscreen
  - ADC/DAC Analog Module
  - ACEX EP1K100 Development Kit

The List Keeps Growing . . .

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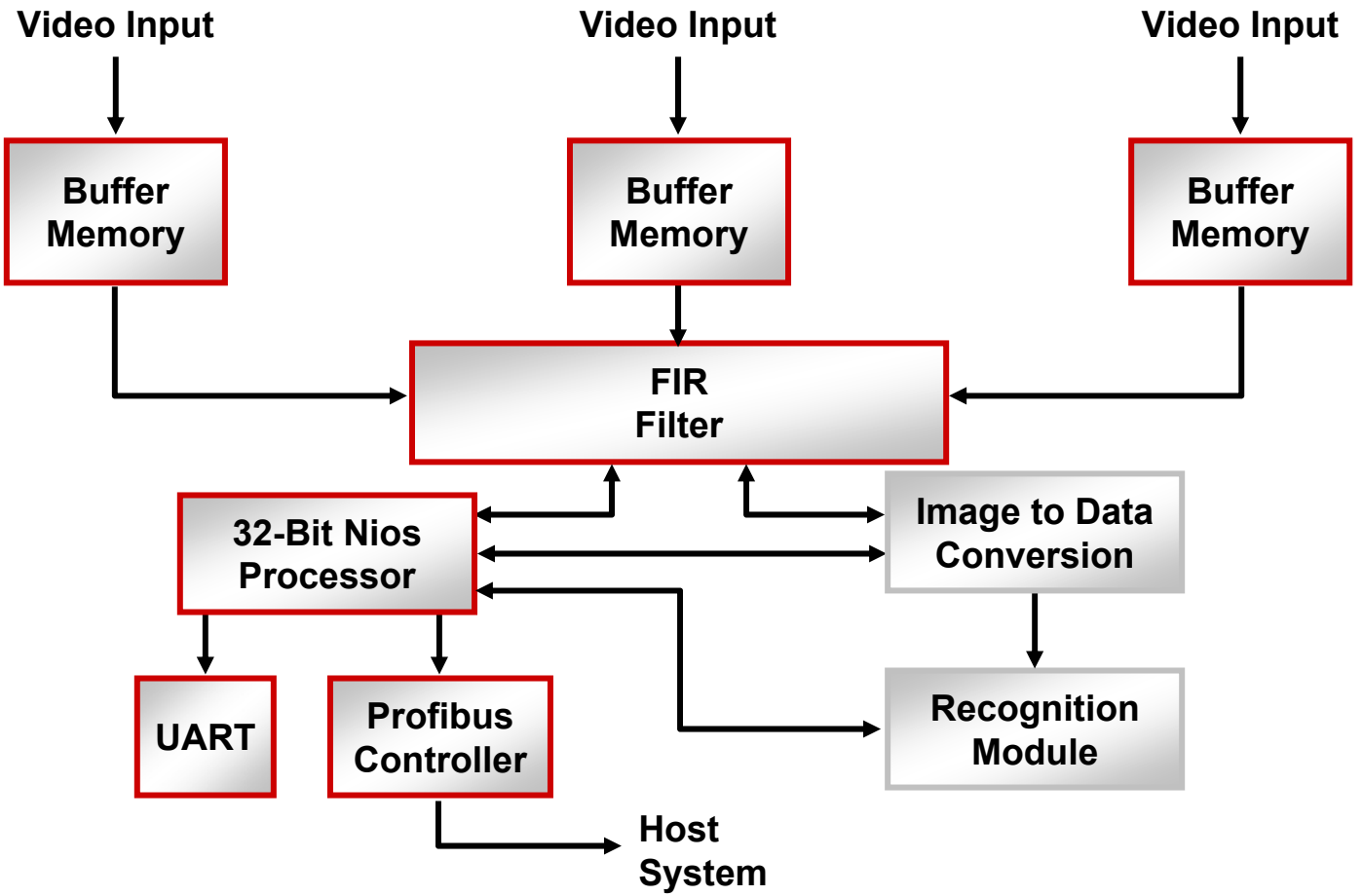
Other Industrial Applications

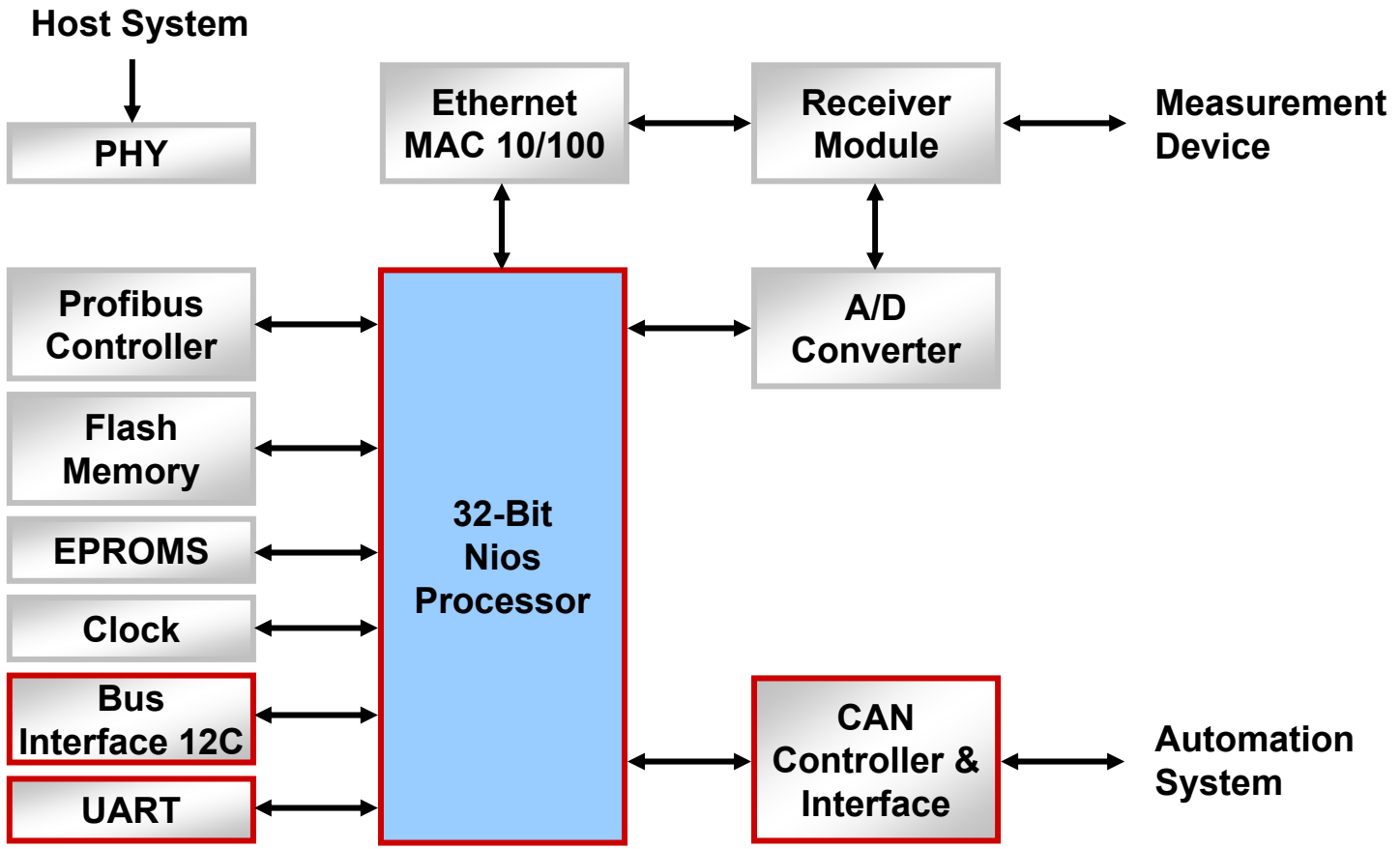
ALTERA.

Factory Automation System



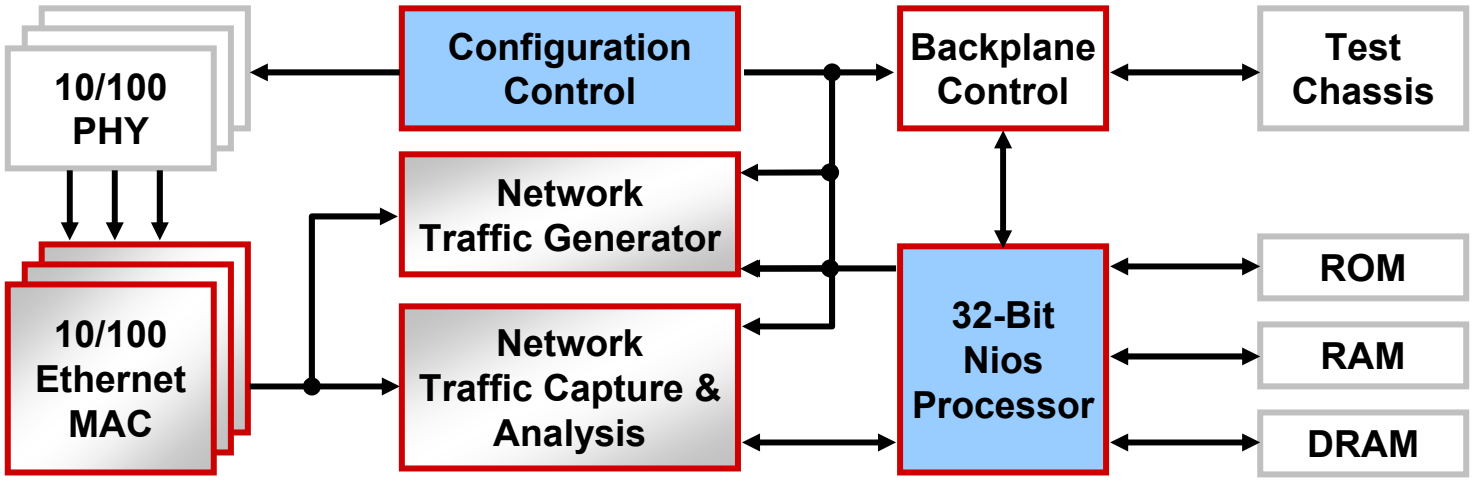
System in Cyclone

Process Control System



System in Cyclone

Network Test Equipment System



System in Cyclone

Summary & Conclusions

- Provides Best All-Round Solution
- Addresses Major Design & Implementation Issues
  - Design Considerations
    - Flexibility ✓
    - Time to Market ✓
    - Reusability ✓
  - Solution Requirements
    - Minimal Cost
    - Manufacturability ✓
    - Device Qualification ✓
    - Remote Accessibility ✓
- Multiple Applications ✓